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RESEARCH ARTICLE

SUSPENDED SEDIMENT RATING CURVE FOR TIGRIS RIVER UPSTREAM AL-AMARAH BARRAGE

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Abstract

In this study, suspended sediment rating curves for sediment concentration and sediment discharge for a section of Tigris River located upstream AL-Amarah barrage, Maysan province. For this purpose, a number of in-site observations were made; many samples were taking from the river during each observation, these samples were filtered and the suspended sediment concentration and the average concentration recorded. Also, for each observation, the river discharge was measured using the ADCP technology. A total number of thirty-six observations were recorded. The rating curves were developed by establishing power relation between sediment concentration (and sediment discharge) as dependent variable and the flow discharge as independent variable. A good agreement between the power relation and the observed data were achieved depending on the value of correlation coefficient R.

Introduction

In an alluvial river, there is a relationship between sediment discharge and river discharge. The sediment transport cannot be viewed as a simple function of hydraulic conditions because many factors are influencing this relationship, such as boundary shear, bed roughness, temperature, fall velocity of the bed material and hydraulic conditions of the river. But generally, the sediment discharge increases with an increase in river discharge, so, sediment rating curves is a good, empirical, method to convert discharge into suspended load estimates.

Measuring the average suspended-sediment concentration in stream-flow is a time-consuming and expensive operation and for these reasons we make considerable use of suspended sediment rating curves.

Sediment rating curves are widely used to estimate the sediment load being transported by a river. A sediment rating curve is a relation between the sediment and river discharges. Such a relationship is usually established by regression analysis, and the curves are generally expressed in the form of a power-law type equation.

Colby (1956) classified the sediment rating curves according to the time base of the basic data that define the curve. Thus, they may be classified as instantaneous, daily, monthly, annual or flood-period curves. [Cited in Al-Ani 1990]

The statistical relationship between suspended sediment concentration, or sediment load, and stream discharge "the sediment rating curve" is commonly takes the power law form [Syvitski 200]:

$$\mathbf{Cs = a\ Q^b}\ \ldots\ldots\ldots\ldots\ldots\mathbf{1}$$

Where, Cs = suspended sediment concentration; Q = discharge; and *a*, and *b* are sediment rating coefficient and exponent, respectively.

The suspended sediment load Qs of a river is similarly related to the discharge by the same rating coefficients,

$$\mathbf{Qs = a\, Q^{b+1}} \text{................2}$$

As the discharge is not measured very frequently, in many cases, the estimation of sediment being transported is a two-step procedure. The measured stage data are used to estimate discharge which, in turn, is used to estimate the sediment concentration. A sediment rating curve is similar to a discharge rating curve, except that the relationship is established between water discharge and sediment concentration or sediment discharge.

Sediment rating curve can be considered a black box type of model and the coefficients a and b has no physical meaning. However, b-coefficient indicates the extent to which new sediment sources become available when discharge increases. The values of b-coefficient obtained for different rivers were used to discuss differences in transport characteristics, a-coefficient is defined as an index of erosion severity; high a-values indicate intensively weathered materials, which can be easily transported. The b-coefficient represents the erosive power of the river. [Chandramohan 2006]

The reach of study

Data needed for the establishment of sediment rating curve was collected in section **No.1** upstream the barrage as shown in figure 1 during the period (1-12-2012 to 31-3-2013) in the winter season. Al-Amarah Barrage (Regulator) was finished and opened in 2005; it's constructed on Tigris River in the location 31° 51.041North and 47° 8.857East, in Amarah city, Maysan governorate.

Fig.1: Location of Al-Amarah Barrage

Field Data measurements

The set of data includes sixty three data record, each record contains the water level (stage), water discharge, and average suspended sediment concentration and calculated the suspended sediment discharge.

Water Discharge Measurements

The ADCP technology was used to measure water discharge, Acoustic Doppler Current Profilers are widely used nowadays in the field of river engineering to measure flow velocities, primarily to determine river discharge [Baranya 2009]. Generally, the device is mounted on a boat that moves across transect of the river as in figure 2. The used ADCP showed in figure 3.

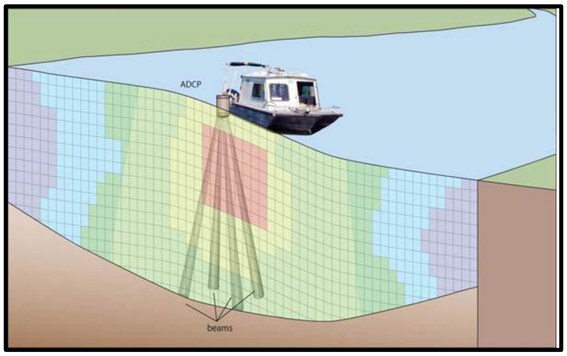


Fig.2: Stream flow measurement using an ADCP

Fig.3: SonTek river surveyor ADCP

Suspended Sediment concentration

Suspended sediment concentration was measured and recorded to determine how much sediment is entrained in the stream flow. Depending on the desired degree of accuracy of the measurements, the number and location of sampling verticals should be selected. Selection of sampling verticals at the ¼, ½ and ¾ width of stream cross-section is convenient and practical.

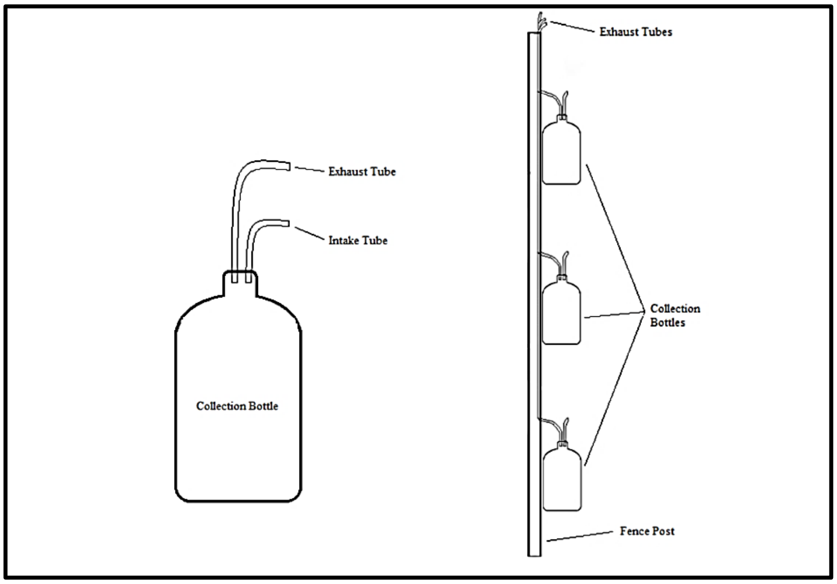
At a given vertical, the suspended load can be sampled by a depth integration method or by a point metered or point-integration method one or more points along the vertical. The depth integration is useful for determination of the suspended-load rate. The point method is used if the vertical suspended-load distribution itself is desired. Proper selection of sampling points in a vertical is of importance. In this study a three samples were taken at each vertical at three depths 0.8d, 0.6d and 0.2d, where d is the depth measured from water surface. A total of nine samples in the transect section were taken each time.

This samplers (or single stage samplers) were constructed using one liter plastic bottles. Two holes were drilled into the cap of each of the bottles and 8mm aluminum tubing was inserted into each hole approximately 3 cm into the bottle (air exhaust tube and intake tube). The area around the tubing was sealed with sealant to ensure that water would not leak into the bottle and to prevent the tubing from sliding in and out of the bottle cap. Several of these units may be mounted at one station (Three bottles with were fastened to a fencepost). The inlets for the samplers were at varying depths according to the depth of vertical; Figures (4) and (5), so that sediment samples from different heights within the water column could be collected. The water-sediment mixture enters whenever the water level rises to the elevation at which the intake tube is placed. Bottles are placed in positions where samples are to be obtained. Such a sampler fills gradually and causes little disturbance to the flow. If the sampler can be placed quickly into the sampling position, no valves are necessary; otherwise control valves to open and close the tubes are essential.

Once suspended sediment samples were collected, the samples were filtered using filter papers. The filters used had a pore size of 0.45μm and pre-dried for 15 minutes in an oven at 105 °C. The weight of the filter paper was measured prior to filtering. The amount of water being filtered was also measured. After the sediment was filtered out of the sample, the sediment and filter paper were placed on a dish and placed in an oven and baked for 24 hours at approximately 105 degrees Celsius to remove water from the sediment. After 24 hours the filter paper with sediment was removed from the oven and weighed. The mass of sediment could then be determined by subtracting the initial filter weight from the weight of the dried sediment and filter. Once the weight of the sediment and the volume of water filtered were determined, the following equation was used to calculate the suspended sediment concentration. [Maidment 1993]

$$\text{Sediment Concentration (Cs)} = \frac{\text{Mass of Sediment (M)}}{\text{Volume of Water (V)}} \ldots\ldots\ldots\ldots\ldots 3$$

Where Cs in ppm or mg/l; M in mg and V in liter



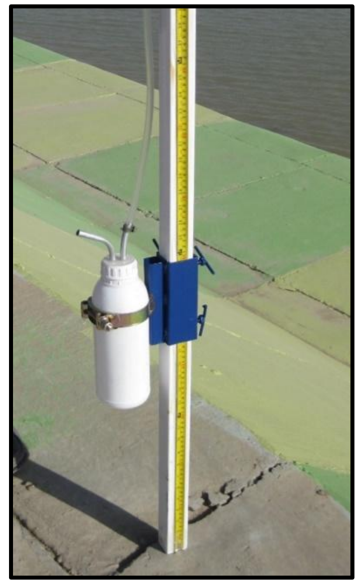


Fig. 4: Suspended Sediments Sampler **Fig. 5: Homemade Sampler**

All data that needed to construct a suspended sediment rating curve were listed in table (1).

Table 1: Data for Sediment Rating Curve

Record No.	Water Stage (m)	Water Discharge (m3/sec)	Avg Sed. Con. (ppm)	Sed. Dis. (kg/sec)
1	5.10	50	127	6.35
2	4.69	47	153	7.19
3	4.85	45	146	6.57
4	4.84	42	134	5.63
5	4.83	40	128	5.12
6	4.82	39	100	3.90
7	4.81	38	155	5.89
8	4.74	37	134	4.96
9	4.69	35	134	4.69
10	4.65	33	143	4.72
11	5.39	64	157	10.05
12	5.80	80	231	18.48
13	5.85	85	205	17.43
14	5.55	76	181	13.76
15	5.69	78	196	15.29
16	5.41	67	161	10.79
17	5.29	63	192	12.10
18	5.56	72	185	13.32
19	5.06	50	155	7.75
20	5.16	56	184	10.30
21	5.26	59	160	9.44
22	5.36	63	189	11.91
23	5.42	66	195	12.87

24	5.48	68	175	11.90
25	5.70	72	130	9.36
26	7.05	136	260	35.36
27	6.00	76	161	12.24
28	5.60	57	185	10.55
29	5.40	48	175	8.40
30	5.98	83	221	18.34
31	5.81	80	196	15.68
32	5.87	83	200	16.60
33	5.88	85	183	15.56
34	5.38	61	160	9.76
35	5.55	67	171	11.46
36	5.60	69	165	11.39

Suspended Sediment Rating Curve

Figure (6), shows the observed suspended sediment concentration rating curve, while figure (7) represents the observed suspended sediment load rating curve. From these figures, the sediment rating curve will take the form:

Suspended Sediment Concentration, $Cs = 23.075\ Q^{0.4834}$ **................4**

Suspended Sediment load (Discharge), $Qs = 0.00231\ Q^{1.4834}$ **................5**

These relationships match well with observed data depending on the Correlation Coefficient, R. The higher the correlation coefficient, the better the variance that the dependent variable is explained by the independent variable.

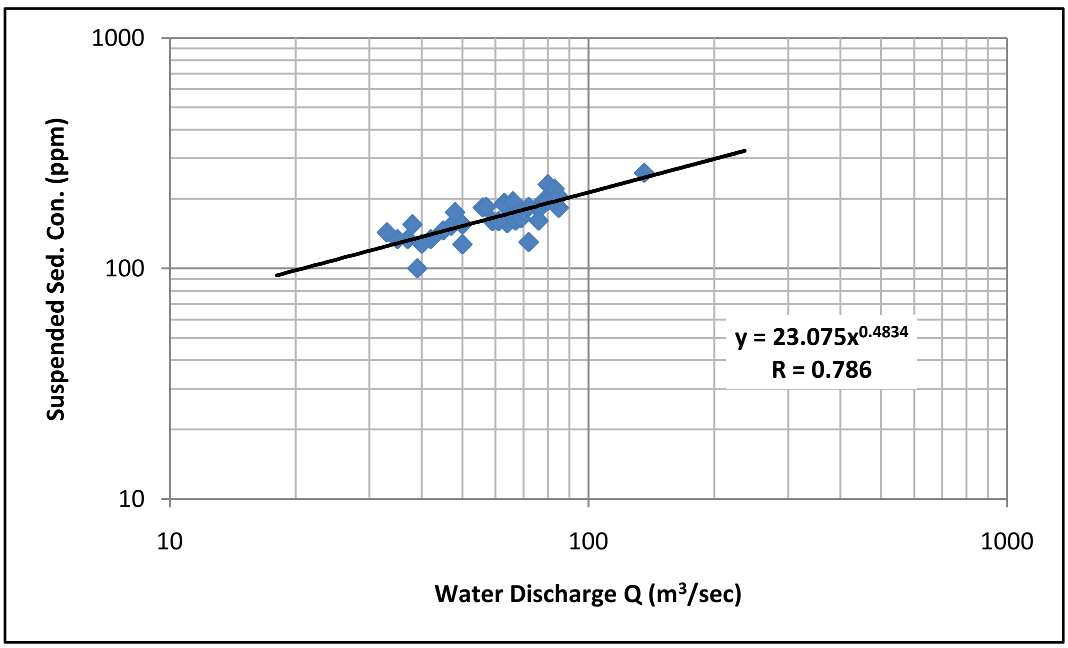


Fig. 6: Observed Suspended Sediment Concentration Rating Curve

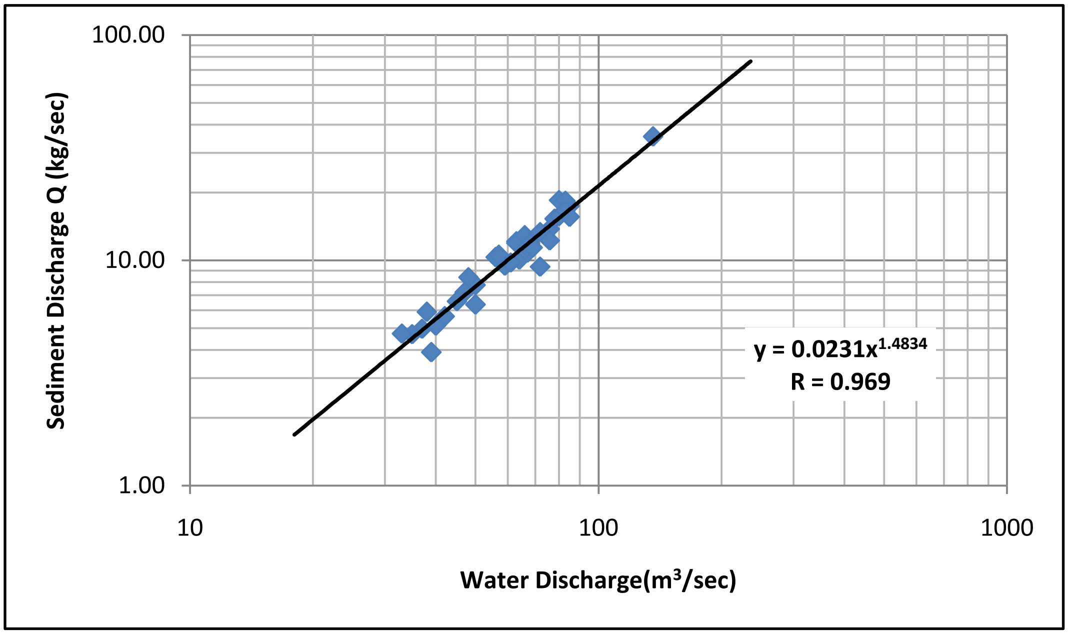


Fig. 7: Observed Suspended Sediment Discharge Rating Curve

Conclusions

This study presents an establishing of sediment rating curves for suspended sediment concentration and loads that reaching Al-Amarah barrage.

According to the result obtained in this study, the following points are concluded:

1- A good matching between the relationship and observed data was achieved, the value of correlation coefficient was 0.79 for sediment concentration rating curve and 0.97 for sediment load rating curve.
2- Depending on the values of R, the sediment load (discharge) rating curve is better in estimating sediment discharge in this reach of the river than estimating its concentration.
3- Rating curves can be improved by getting more data from field observations, and by taking bed load into account (total sediment load rating curve). Also, the sediment rating curve improves when it is developed by partitioning the data into monthly basis.

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